Resistance and Electric Power

Recall:
Voltage, V is the electrical energy per unit charge, V=energy/q in units of volts,1 V= 1J/C (analagous to height and gravitational energy)

Current, I is the amount of charge passing per unit time - direction is positive charge (opposite of electron flow)

I=q/t units Ampère, A=C/s

Resistance, R

is the ratio of Voltage across an element to current through the element

R=V/I

units: Ohms, Ω = V/A = Js/C^2

Let's look at the voltage across and the current through some circuit elements

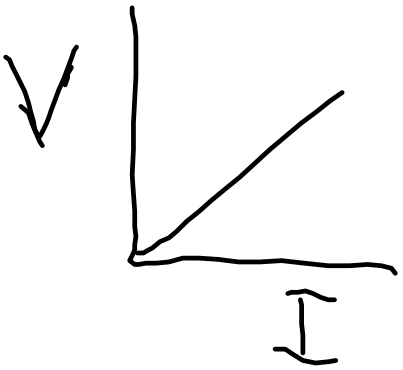
Resistor a light bulb and a LED

VI = J/C x C/s = J/s hey that's Watts, W unit for

power, P=VI

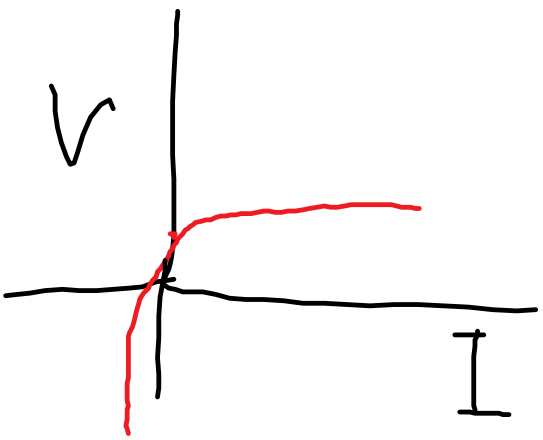
Element	V(V)	I(A)	R=V/I	P=VI	description
Resistor	1.7	4.8mA	354Ω	8.2mW	not much
	1.9	5.2mA	365Ω	9.9mW	ditto

For an Ohmic device, the resistance is constant over a range of Voltages and currents.



For a non-ohmic device, the resistance changes.

diodes



the resistance is still the ratio of V/I at that point and the power output is still VI at that point.

Resistors assume to be Ohmic
what's the point of resistors?

They dissipate electrical energy as heat, so they

1. can be used to heat stuff like a stove/oven
2. can protect sensitive elements that smoke and fry with too much heat.
3. tune frequencies in LCR circuits (old radios)
4. control the voltage - variable resistors are called rheostats or potentiometers - control potential.

eg.

My kettle is listed at 1.2 kW on a 120V input.

a) How much energy as heat is produced in 2.0 minutes?
b) what is the current through the element of the kettle?
c) what is the resistance of the kettle element?
d) if only 1.1 x 10^5 J are transferred to the water, what is the efficiency of the kettle? Where did the excess energy go?

p478 Q21-31 odds

Horsepower, 1 hp = 746W

My kettle is listed at 1.2 kW on a 120V input.

a) How much energy as heat is produced in 2.0 minutes?

energy = power x time = 1.2 x 1000 J/s x 2 x 60s

= 1.4x10^5 J or 140 kJ

= 1.4×10^5 J or 140 kJ

b) what is the current through the element of the kettle?

P=VI so I=P/V = 1200/120=10 A

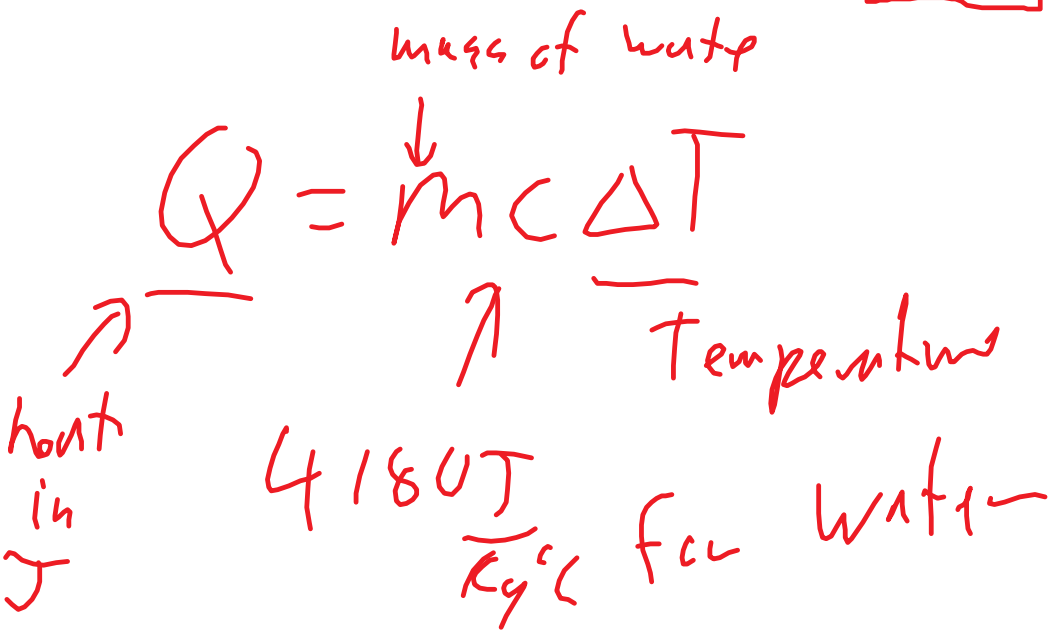
c) what is the resistance of the kettle element?

R=V/I = 120V/10A = 12 Ω

d) if only 1.1×10^5 J are transferred to the water, what is the efficiency of the kettle? Where did the excess energy go?

efficiency = energy out/ energy in x 100%

= 1.1×10^5J/1.4×10^5J x100% = 79%



Recall:

Voltage, V, the energy per unit charge

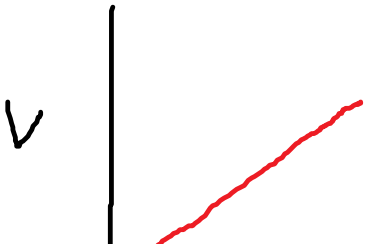
V=energy/q in volts 1V=1J/C
(like height and gravitational energy)

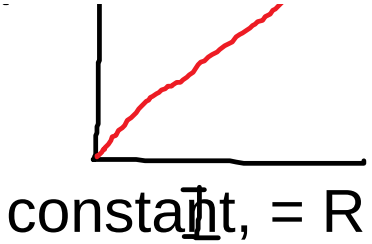
Current, I, the amount of charge passing per unit time, in Ampères, 1A=1C/s

Let's look at the current and voltage properties of a resistor and an LED light.
unit analysis
VI= VA = J/C x C/s = J/s = Watt, W the unit of power, so P=VI

Element	V(V)	I(mA)	R=V/I (Ω)	P=VI (W)	observe
resistor	5.5	16.1	0.34 kΩ	89mW	not much
resistor	11.6	33.5	0.35 kΩ	389mW	ditto
resistor					
LED	1.9	1.9	1.0 kΩ	3.6mW	bright
LED	1.8	1.0	1.8 kΩ	1.8mW	less bright
LED					

Ohmic elements - the resistance, R = V/I in ohms, Ω, is constant over a range of voltages.

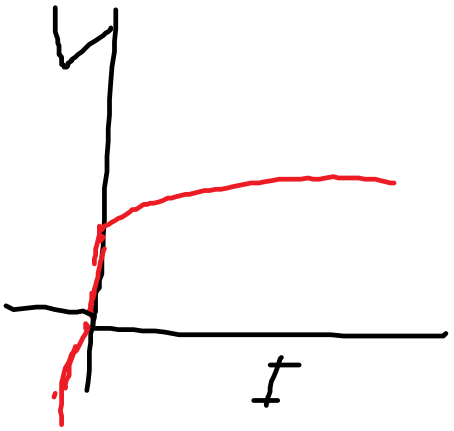




slope is constant, = R

non-ohmic element - the resistance changes

LED - light emitting diode



slope is not = R, R is just the ratio of V/I for a particular set of V and I.

What is a resistor? What is it for?
it can control the current for a set voltage but usually it is used to transform electrical energy into heat or light.
light bulb - changes electrical energy into light and heat.
electrical stove/oven changes electrical energy into heat.
dissipate heat to protect sensitive circuit elements
variable resistor - called a rheostat or potentiometer - controlling the voltage

eg. my kettle is listed at 1500W for a 120V input. What is the

a) current through the heating element?
b) how much charge goes through the element in 2.0 minutes?
c) resistance of the heating element?
d) how much energy is used by the element over 2.0 minutes?
e) if you measure the heat absorbed by the water as 1.4×10^5J, how much energy is lost? What is the efficiency of the kettle? Where did the lost energy go?

p478 Q21-31 odds (Q1-9 odds)

eg. my kettle is listed at 1500W for a 120V input. What is the

a) current through the heating element?
P=VI I=P/V = 1500W/120V = 12.5A

a) how much charge goes through the element in 2.0 minutes?
q=It = 12.5 A x 120s = 1500C

a) resistance of the heating element?

R=V/I = 120/12.5=9.6 Ω
or $R=V^2/P = 120^2/1500 = 9.6\Omega$

a) how much energy is used by the element over 2.0 minutes?

energy = Pt = 1500W x 120s
1500x120=180000 = 180kJ

b) if you measure the heat absorbed by the water as 1.4 x 10^5J, how much energy is lost? What is the efficiency of the kettle? Where did the lost energy go?
40 kJ is lost (180-140)
efficiency = 140kJ/180kJ x 100%
= 78%
energy is lost to the air through conduction, convection and some radiation.

$Q=mc\Delta T$
Q is heat
m is mass
c is specific heat capacity, water = 4180J/kg^oC
T is temperature

Resistance and Power

Recall:
What is voltage and current?

Voltage, V, is the energy per unit charge,

V= energy/q in units of Volts, V 1V=1J/C

Current, I, is the amount of charge passing per unit time, I=q/t, in units of Ampère, A 1A = 1C/s

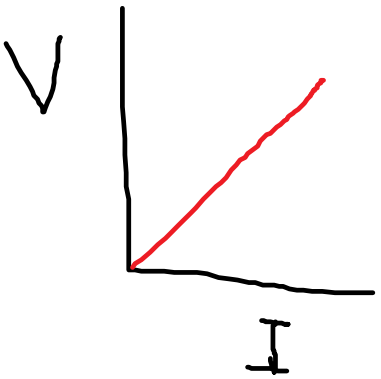
What is resistance, R?
define resistance as the ratio of voltage to current
R=V/I units of Ohms Ω= V/A

If an element has a large resistance, the current will be less for the same voltage.

Let's try to observe the voltage/current properties of a resistor and an LED light.
unit analysis
VxI = J/C x C/s = J/s = W = unit for power
P=VI

Element	V(V)	I(A)	R=V/I(Ω)	P=VI(W)
Resistor 1	0.047	133 μA	350Ω	6.3 μW
2	0.054	149 μA	360Ω	8.0 μW
3	0.023	66 μA	350Ω	1.5 μW
LED	1.7	10 μA	0.17 MΩ	17 μW
	1.8	93 μA	19kΩ	170μW
	1.0	0 μA	??? infinite?	0 W

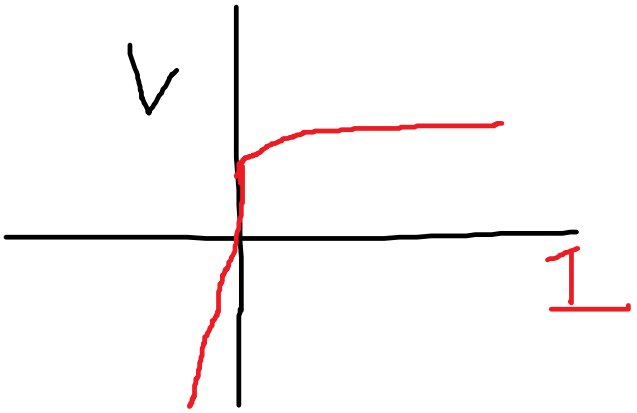
Ohmic circuit elements have a constant resistance over a range of voltages - Resistors.



slope is the resistance, R = V/I

non- Ohmic circuit elements have a variable resistance. - most lamps and definitely LEDs

LED



slope is not the resistance, R=V/I at each point

eg. My kettle is rated at 1500W when connected to a 120V wall socket. It takes 2.0 minutes to boil 350 g of water, heat capacity 4180 J/kgºC from 15ºC to boiling at 100ºC.

a) What is the current through the heating element?
P=VI I=P/V = 1500/120=12.5 A

b) How much charge goes through the element in 2.0 minutes?
I=q/t so q = It = 12.5x2x60=1,500 C

c) How much energy is required to heat 350 g of water

from 15 to 100ºC (Q=mcΔT)
Q= 0.35x(4180)x(100-15)=124355.0 =124kJ

d) How much energy does the kettle require if it takes 1500W for 2.0 minutes?
P=energy/time energy =Pt = 1500x2x60=180000 =180kJ

e) what is the efficiency of the kettle? Where did the waste energy go?
efficiency = energy out/energy in x100%
= 124kJ/180kJ x100 = 124/180=0.6889
69% energy is lost to steam and conduction/convection with the air

f) what is the resistance of the kettle element?
120/12.5=9.6
R=V/I = V^2/P 120x120/1500=9.6 Ω
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